Focus Underwater laser scanning

3D surveying of underwater infrastructure and bathymetric measurements for deeper insights

Climate change is causing our coastlines to change rapidly. Laser-based systems are making it easier to perform topographic mapping.

Using measurement technology to discover what lies beneath the water's surface can be difficult. At present, underwater structures are generally inspected by divers. Visual inspections like this are performed with the help of image and video recordings, but lack objectivity and are time-consuming, not to mention dangerous. Other optical methods, such as laser triangulation and photogrammetry, have a limited working range and are sensitive to turbid water. The bathymetric surveying of shallow bodies of water – especially in coastal areas and waterways – is just as complex and laborious. To date, there is no standard, automated process for measuring both the topography of the surrounding land and the topography of the water's floor because these areas are often inaccessible to sonar systems. This means that manual surveying using a GNSS pole is often the only option remaining. However, the resolution attainable using this method is limited and the measurement process is very time-consuming and expensive.

LiDAR (light detection and ranging) technology using pulsed lasers offers many advantages when performing underwater 3D measurements and bathymetric measurements. LiDAR systems provide more precise and detailed measurements than, for example, camera or sonar systems and enable direct, true 3D data to be captured – even across relatively large distances. Water nevertheless poses a number of fundamental challenges, which is why optical systems are currently hardly ever used for underwater measurements. Water attenuates light significantly; furthermore, turbid matter in water cause light to disperse and dazzle the sensors. Over the past few years, researchers at Fraunhofer IPM have successfully overcome these challenges. The team has so far developed two systems – the Underwater LiDAR System ULi and the Airborne Bathymetric System ABS.

Measuring structures down to the millimeter – at depths of up to 300 meters

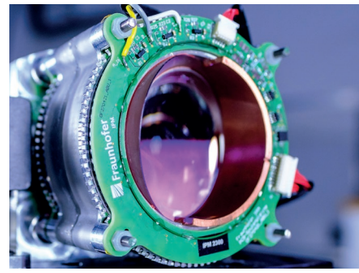
The underwater laser scanner ULi measures 3D structures in the water and can be operated statically or by being moved by a underwater ROV (remotely operated vehicle) or boat. This allows damage to underwater infrastructure like dams, wind turbine foundations, pipelines and data cables to be identified in good time. The system can also detect biofouling, which sometimes accumulates in layers several centimeters thick on ship hulls, pushing up fuel consumption.

ULi can dive to depths of up to 300 meters, capturing objects with precision in the millimeter range across distances of several tens of meters. The following applies: the clearer the water, the better the measurement results. The measurement distance is around twice the range of vision and structures much smaller than a centimeter can be resolved. The system provides measurements that are up to ten times more precise than sonar systems and creates a precise 3D model of the object being scanned. ULi captures underwater infrastructure using the pulsed time-of-flight method with a laser light with a wavelength of 532 nm and a sampling frequency of up to 100,000 measuring points per second. The measurement beam is deflected using two rotating Risley prisms, allowing the scanner to capture the entire field of view without the sensor needing to be moved.

Ultra-lightweight LiDAR scanner efficiently takes measurements from the air

Laser-based systems are efficient at generating bathymetric maps of bodies of water with a relatively high resolution. However, the few laser bathymetry systems already available are large and weigh up to 200 kilograms. The ABS with a weight of just around 3 kilogram is just the size of a shoe box and can be mounted on standard drones. Its low weight means that users do not need to go through the complex and expensive process of applying for flight permits. The LiDAR scanner measures the topography of the water's floor and surrounding areas using the multiwavelength principle, which involves deploying two laser beams with different wavelengths. The advantage: By using two perfectly superimposed pulsed lasers, the undesirable effect of light refraction is corrected, which makes the water appear optically less deep than it actually is. The measurements are therefore much more precise than those taken with just one laser beam. The infrared measurement beam (1,064 nm) does not penetrate the water, allowing it to provide information on the water's surface. It can also be used to detect vegetation, especially in coastal areas. It does this by taking measurements at up to twice the Secchi depth – i.e. two times the visual depth of the water – with a precision of up to 10 cm.

Signal processing presents a particular challenge when taking laser measurements in water. The reflected light contains different echoes from the water's surface, from particles in the water and from the water's floor. To separate this echo sequence in order to extract information on the topography being investigated, a full waveform analysis of the measurement data must be performed. Even the smallest of echoes can be extracted and precisely recorded using specially developed algorithms. The integration of GNSS data allows the flight trajectory to be determined and combined with the LiDAR data to generate a complete georeferenced 3D model.



A look inside: The ULi underwater laser scanner can dive to depths of up to 300 meters.

> "LiDAR systems provide more precise measurements than camera or sonar equipment and produce 3D models."
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> *Dr. Christoph Werner, Group Manager*

Water basin for test measurements
We have been testing our LiDAR systems in a water basin on our premises since 2022. Measuring 40 meters long, 3 meters wide and 2 meters deep, the basin is long enough to perform test measurements. The scanners can be moved above the water's surface on a mobile platform and can also be submerged in the water. Filtration equipment is used to add or extract specific quantities of turbid matter. The basin is the only research facility of this size.